

What is claimed is:

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1. A method for designing a progressive addition lens, comprising a.) describing a progressive addition surface; and b.) optimizing the surface using a merit function of the formula:

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$$MF = MF_{\text{blur}} + MF_{\text{power}} + MF_{\text{other}}$$

wherein:

MF_{blur} is a merit function that controls image blur;

MF_{power} is a merit function that controls the mean sphere power; and

15 MF_{other} is a merit function that controls constraints on cosmetics and manufacturability.

2. The method of claim 1, wherein the surface is described as a continuous, a differentially continuous, or a twice differentially continuous surface.

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3. The method of claim 1, wherein the surface is described according to the equation:

$$\text{sag}_{x,y} = \text{Delta}_{x,y} + \frac{c \cdot r^2}{1 + \sqrt{1 - (1 + k) \cdot c^2 \cdot r^2}} + \alpha_1 \cdot r^2 + \alpha_2 \cdot r^4 + \alpha_3 \cdot r^6 + \alpha_4 \cdot r^8 + \dots$$

25 wherein:

c is a surface curvature;

r is a radial distance from an optical axis of the lens;

k is a conic constant;

$\alpha_1, \alpha_2, \alpha_3, \alpha_4$ each are a coefficient; and

30 $\text{Delta}_{x,y}$ is a delta sag that is a function of x and y.

- 5 4. The method of claim 1, 2, or 3, wherein

$$MF_{\text{blur}} = \sum_{\theta_x} \sum_{\theta_y} W_{\text{rms}_{\theta_x, \theta_y}} \left(\text{RMS}_{\theta_x, \theta_y} \right)^2$$

wherein:

- θ_x is a horizontal eye rotation angle;
 10 θ_y is a vertical eye rotation angle;
 $\text{RMS}_{\theta_x, \theta_y}$ is an RMS spot size calculated at an image of an eye lens; and
 $W_{\text{rms}_{\theta_x, \theta_y}}$ is a weight for a field position.

5. The method of claim 1, 2 or 3 wherein MF_{power} is:
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$$MF_{\text{power}} = \sum_{\theta_x} \sum_{\theta_y} W_{\Phi_{\theta_x, \theta_y}} \left(\Phi_{\theta_x, \theta_y} - P_{\theta_x, \theta_y} \right)^2$$

wherein:

- P_{θ_x, θ_y} is a desired sphere power;
 θ_x and θ_y are the eye rotation angles;
 20 $\Phi_{\theta_x, \theta_y}$ is actual sphere power; and
 $W_{\Phi_{\theta_x, \theta_y}}$ is the weighting for that particular field point on the power error.

6. The method of claim 4, wherein MF_{power} is:

$$MF_{\text{power}} = \sum_{\theta_x} \sum_{\theta_y} W_{\Phi_{\theta_x, \theta_y}} \left(\Phi_{\theta_x, \theta_y} - P_{\theta_x, \theta_y} \right)^2$$

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wherein:

- P_{θ_x, θ_y} is a desired sphere power;
 θ_x and θ_y are the eye rotation angles;

$\Phi_{\theta_x, \theta_y}$ is actual sphere power; and

$W_{\Phi_{\theta_x, \theta_y}}$ is the weighting for that particular field point on the power error.

7. A method for designing a progressive addition lens, comprising a.)
 5 describing at least two progressive addition surfaces; and b.) optimizing the surfaces
 using merit functions of the formula:

$$MF = MF_{\text{blur}} + MF_{\text{power}} + MF_{\text{other}}$$

10 wherein:

MF_{blur} is a merit function that controls image blur;

MF_{power} is a merit function that controls the mean sphere power; and

MF_{other} is a merit function that controls constraints on cosmetics and
 manufacturability.

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8. The method of claim 7, wherein the surfaces are each independently
 described as a continuous, a differentially continuous, or a twice differentially
 continuous surface.

- 20 9. The method of claim 7, wherein the surfaces are each described according to
 the equation:

$$\text{sag}_{x,y} = \text{Delta}_{x,y} + \frac{c \cdot r^2}{1 + \left[1 - (1 + k) \cdot c^2 \cdot r^2 \right]} + \alpha_1 \cdot r^2 + \alpha_2 \cdot r^4 + \alpha_3 \cdot r^6 + \alpha_4 \cdot r^8 + \dots$$

wherein:

c is a surface curvature;

25 r is a radial distance from an optical axis of the lens;

k is a conic constant;

$\alpha_1, \alpha_2, \alpha_3, \alpha_4$ each are a coefficient; and

$\text{Delta}_{x,y}$ is a delta sag that is a function of x and y .

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10. The method of claim 7, 8, or 9, wherein MF_{power} is :

$$MF_{\text{power}} = \sum_{\theta_x} \sum_{\theta_y} W_{\Phi_{\theta_x, \theta_y}} \left(\Phi_{\theta_x, \theta_y} - P_{\theta_x, \theta_y} \right)^2 + W_{\text{add}_{\theta_x, \theta_y}} \left[\left(\text{AddF}_{\theta_x, \theta_y} - PF_{\theta_x, \theta_y} \right)^2 + \left(\text{AddB}_{\theta_x, \theta_y} - PB_{\theta_x, \theta_y} \right)^2 \right]$$

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wherein

θ_x is a horizontal eye rotation angle;

θ_y is a vertical eye rotation angle;

RMS_{θ_x, θ_y} is a RMS spot size calculated at an image of an eye lens;

10 $W_{rms_{\theta_x, \theta_y}}$ is a weight for a field position;

$\text{AddF}_{\theta_x, \theta_y}$ is a calculated add power on a front surface of the lens;

$\text{AddB}_{\theta_x, \theta_y}$ is a calculated add power on a back surface of the lens;

PF_{θ_x, θ_y} is a target for an add power value for the front surface;

PB_{θ_x, θ_y} is a target for an add power for the back surface; and

15 $W_{\text{add}_{\theta_x, \theta_y}}$ is a weighting.

11. The method of claim 7, 8, or 9, wherein MF_{power} is :

$$MF_{\text{power}} = W_{\text{add}_{\text{far}}} \left[\left(\text{AddF}_{\text{far}} - PF_{\text{far}} \right)^2 + \left(\text{AddB}_{\text{far}} - PB_{\text{far}} \right)^2 \right] + \left[\sum_{\theta_x} \sum_{\theta_y} W_{\Phi_{\theta_x, \theta_y}} \left(\Phi_{\theta_x, \theta_y} - P_{\theta_x, \theta_y} \right)^2 \right]$$

20 wherein

θ_x is a horizontal eye rotation angle;

θ_y is a vertical eye rotation angle;

RMS_{θ_x, θ_y} is a RMS spot size calculated at an image of an eye lens;

$W_{rms_{\theta_x, \theta_y}}$ is a weight for a field position;

25 $\text{AddF}_{\theta_x, \theta_y}$ is a calculated add power on a front surface of the lens;

$\text{AddB}_{\theta_x, \theta_y}$ is a calculated add power on a back surface of the lens;

PF_{θ_x, θ_y} is a target for an add power value for the front surface;

PB_{θ_x, θ_y} is a target for an add power for the back surface; and

$Wadd_{\theta_x, \theta_y}$ is a weighting.

12. The method of claim 7, 8, or 9, wherein MF_{blur} is:

$$MF_{blur} = \sum_{\theta_x} \sum_{\theta_y} \left[W_{rms_{\theta_x, \theta_y}} \cdot (RMS_{\theta_x, \theta_y})^2 + W_{ast_{\theta_x, \theta_y}} \cdot (AstF_{\theta_x, \theta_y} - AF_{\theta_x, \theta_y})^2 \right] \quad (IX)$$

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wherein:

$AstF_{\theta_x, \theta_y}$ is either the surface astigmatism from the front surface or the contribution to the total lens astigmatism as seen by the eye from the front surface; and

$Wast_{\theta_x, \theta_y}$ are the weights placed on the unwanted astigmatism.

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13. The method of claim 10, wherein MF_{blur} is:

$$MF_{blur} = \sum_{\theta_x} \sum_{\theta_y} \left[W_{rms_{\theta_x, \theta_y}} \cdot (RMS_{\theta_x, \theta_y})^2 + W_{ast_{\theta_x, \theta_y}} \cdot (AstF_{\theta_x, \theta_y} - AF_{\theta_x, \theta_y})^2 \right] \quad (IX)$$

wherein:

15 $AstF_{\theta_x, \theta_y}$ is either the surface astigmatism from the front surface or the contribution to the total lens astigmatism as seen by the eye from the front surface; and

$Wast_{\theta_x, \theta_y}$ are the weights placed on the unwanted astigmatism.

14. The method of claim 11, wherein MF_{blur} is:

$$MF_{blur} = \sum_{\theta_x} \sum_{\theta_y} \left[W_{rms_{\theta_x, \theta_y}} \cdot (RMS_{\theta_x, \theta_y})^2 + W_{ast_{\theta_x, \theta_y}} \cdot (AstF_{\theta_x, \theta_y} - AF_{\theta_x, \theta_y})^2 \right] \quad (IX)$$

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wherein:

$AstF_{\theta_x, \theta_y}$ is either the surface astigmatism from the front surface or the contribution to the total lens astigmatism as seen by the eye from the front surface; and

25 $Wast_{\theta_x, \theta_y}$ are the weights placed on the unwanted astigmatism.

15. The method of claim 1 or 7, further comprising c.) determining a set of coefficients to describe the lens surface to minimize the value of the merit function.
- 5 16. The method of claim 15, wherein step c.) is carried out by (i) selecting optimization variables that are a curve for a front surface and a curve for the back surface of the lens; and (ii) minimizing MF_{other} .
- 10 17. A progressive addition lens, comprising a first and a second progressive addition surface, wherein an unwanted astigmatism for the first progressive addition surface is greater than 0.25 diopters.
- 15 18. A progressive addition lens, comprising a first progressive addition surface having a first add power and a second progressive addition surface having a second add power, wherein a maximum unwanted astigmatism of the first progressive surface is greater than the first add power.
- 20 19. A progressive addition lens, comprising a first progressive addition surface, a second progressive addition surface, and a total lens add power that is about the sum of the add power of the first and second progressive surfaces, wherein a maximum unwanted astigmatism of the lens is less than about one-half of the total lens add power.